Level 1 Trigger Rate Control for GLAST:
A Proposed Solution

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The rate of background cosmic ray triggers that GLAST may need to deal with is higher than originally thought due to albedo fluxes coming from the Earth's atmosphere that are not included in the CHIME or CRÈME models. The fluxes have been reported by Gusev et al. 1985, Geomagnetism and Aeronomy, 25, #4, 462 (recently remeasured by Ting et al. 1999, CERN Courier). These fluxes were known from the early days of space observations. There is a theoretical paper by Ray (1962, JGR, 67, 3289) that explains the basic phenomenon. More serious measurements were made in the mid '60s (see Verma, 1967, JGR, **72**, 915 and Israel, 1967, JGR, **74**, 4701) accompanied by more detailed theoretical modeling (Verma, S. D., 1967, Proc. Indian Academy of Sciences, Section A, **56**, 125-143).

The Earth is bright in particles, mostly low energy electrons, as well as photons. The EGRET has two lines of defense against these electrons. The A-dome can veto them and the trigger is directional preventing particles from below the limb from triggering the detector. But what will the rates be in the case of GLAST? These particles can come under the skirt of the ACD, or through the side ACD tiles and make "3-in-a-row" triggers.

The EGRET rates for an orbit that does not pass through the SAA are shown in Figure 1. The top panel is the A-dome rate and represents the latitude variation in the flux. Note also the impact of looking at the Earth (albedo) on this rate. These high "singles" rates are consistent with 100 - 1000 keV soft photons coming off the atmosphere. One can reproduce the A-dome rate of up to 0.6 counts/(cm^2 s) by integrating the spectrum of photons moving upward (see Ling, 1975, JGR, **80**, 3241). Using the 1975 Ling model for atmospheric soft gamma rays may not be optimal. He overestimated the upward-moving component by a factor of 3-4 because of his assumptions about the production. Observations by the Riverside group and the MPE group (see Schonfelder et al. 1977, ApJ, **217**, 306, for a comparison) showed that the gamma rays have the same sort of horizon peak seen at higher energies, only not quite as pronounced as predicted by Ling. But the EGRET threshold is lower than assumed in the calculation above and the spectrum is steep, so the A-dome rate is not surprising and is probably dominated by Compton electrons produced by hard X-rays and low energy gamma rays in the 2 cm thick dome. In fact, the EGRET A-dome was swamped and rendered useless by X-rays from a solar flare. Thus, photon albedo probably explains a significant fraction of EGRET's average A-dome rate of 0.1 counts per (cm^2 s).

Gusev et al. (1985), who measured the albedo fluxes at altitudes near 500 km on Interkosmos-17 found latitude dependent fluxes looking towards the horizon. Their figure 1 has protons from west as "x" and from east as "." (dots). The figure shows the integral flux above the local cutoff rigidity. For reference, at 28 degrees inclination, the orbit cutoff is about 4 GV at minimum and goes up to about 20 GV.

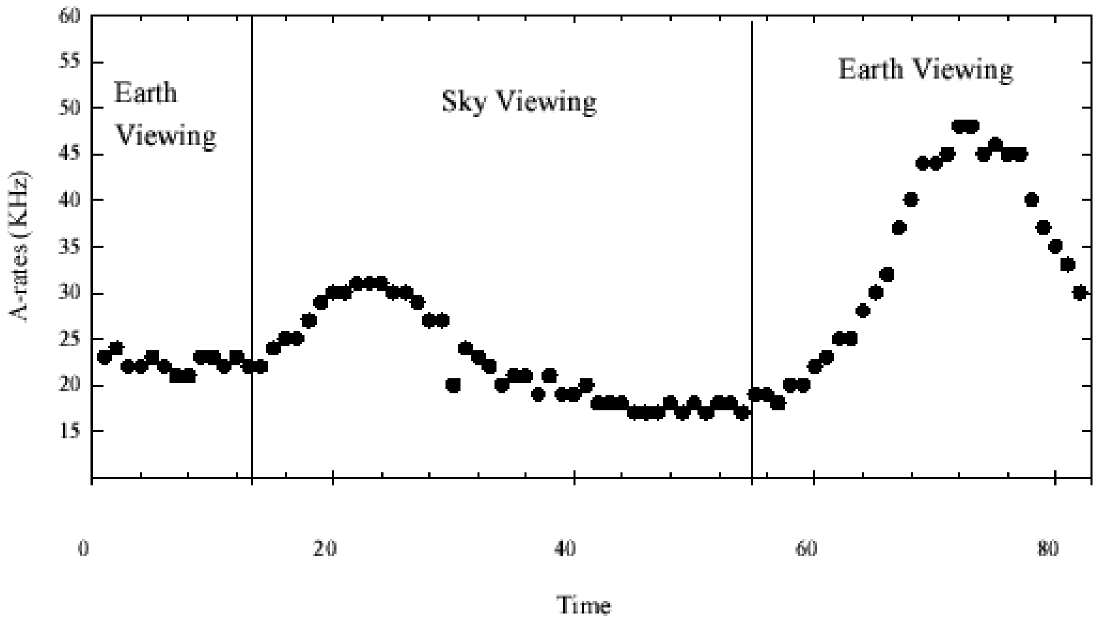

Figure 1: The EGRET anti-coincidence dome rate for an orbit that does not pass through the South Atlantic Anomaly.

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If we assume the four sides of GLAST are illuminated by this flux, roughly 5 x 10^2 per (m^2 s sr), we get a maximum rate of more than 10 kHz as follows:
500 (m^2 s sr)$^{-1}$ * 2 π sr *1.6 m * 0.63 m * 4 sides * 0.6 (probability of side entering event to make "3-in-a-row" trigger) = 12 kHz orbit maximum.
The orbit average cutoff is more like 10 GV where the flux is a factor of 2 less towards the west and 4 less towards the east. Since GLAST has one side looking east and another looking west, we see something like the average of the east and west rate or 4 kHz orbit average through the sides of GLAST.

The Gusev paper has another interesting number: on page 464 it says " ... explained by the presence in the vicinity of the equator of a flux of albedo protons with E> 0.5 GeV, equal to 60 (m^2 s sr)$^{-1}$." Assuming this is isotropic, it gives a rate of 1 kHz through GLAST, in the ballpark of the Ting measurements made within 17^o of the geomagnetic equator.

Our data system is power goes up as it handles the higher rates and dead time increases; we are running out of our margin for even average rates. **We need to have a way (or ways) to throttle the L1 trigger rate.** At Santa Cruz, we came up with a scheme of putting the top layer into coincidence with the ACD to veto background events. I had guessed at Santa Cruz that it would give us a factor of 3, but Monte Carlo runs show something less, more like a factor of 2. This will not work if most of the background comes in through the sides. We have been thinking about adding the criterion of rejecting, at L1, events with 2 or more ACD tiles hit. (We still assume the veto will be over-ridden if the energy deposit in the calorimeter is above the "high threshold"; we'll call it the "hi-E-threshold").

Jay and Heather (also the Univ. of Washington group) have looked at the effect on rates for these two schemes using an *isotropic* proton, high-energy electron mix, background onto GLAST (including the hi-E-threshold over-ride).

1) Reject events in which the "top layer" + "hit ACD in nearest neighbor set of tiles" (those ACD tiles over and on the top side row next to each tower): this cuts the proton rate by a factor of 2.2.
2) Reject events with 2 or more ACD tiles struck: this cuts the proton rate by a factor of 3.2.
3) Do both 1) and 2): this cuts the proton rate by a factor of 5.4.

These requirements are designed to handle the background of obliquely entering events that light up at least one side tile. Note that both does less well than the product because there some events either cut would eliminate.

We have examined the loss of efficiency for our best photons, those within 30 degrees of normal and entering near the center of the instrument using these trigger schemes. The loss is a few percent and peaks between 3 and 30 GeV as one would expect. The hi-E-threshold override criterion was optimized to be >15 crystals with > 100MeV deposit. A lower "hi-E-threshold" override makes the rate go back up and higher "hi-E-threshold" allows photons of higher energy and hence more backsplash to be self-vetoed, so there is an optimum setting of the "hi-E-threshold". The effect is seen in Figure 2 where we have expanded the vertical axis to make evident the impact as a function of energy. The initial L1 trigger efficiency (to get a "3-in-a-row") is indicated by the scale on the right side by the curve connected by -x-. The reduction in efficiency due to both cuts described above is shown as the difference between the two blue curves (the dark one is after the cuts, the light before). Note that this trigger has essentially no impact on the photon acceptance above 20 GeV because of the "hi-E-threshold" veto override.

At high rates the dead time increases. The throttles increase the live time and compensate for the loss of photons. There will be some rate TBD above which these L1 trigger throttles will actually increase the photon yield.

We don't see any reason not to implement these cuts at L1. We will have to be careful to monitor the ACD noise rates for individual tiles and remove any tile which "runs wild".

We were concerned about the possible impact on gamma ray bursts: Are the fluxes high enough for bursts to lose photons because of self-veto by triggering more than one ACD tile? The analysis below shows this is unlikely. The chance of two conversions (and therefore a veto under the proposed L1 rate control criteria) is less than 1.5% (see Appendix G).

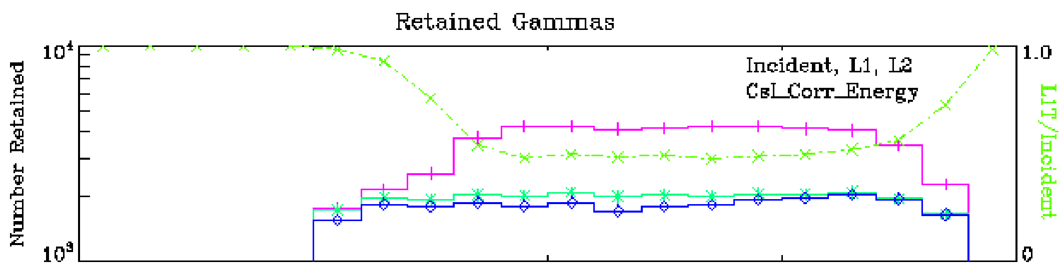

Figure 2: The fraction of gamma rays retained as a function of energy. The purple curve is the incident spectrum used (equal numbers of photons per decade above 100 MeV). The pink curve is the spectrum of converted photons (it's not SuperGLAST). The light blue are those accepted as "good" with standard L1 trigger and the dark blue are those that are accepted with the additional L1 trigger throttles described above. The L1 trigger rate is reduced by a factor of 5.4 in going from light to dark blue. Overall efficiency of approximately 50% is indicated by the pale green curve using the right hand linear scale.

Appendix G: Gamma-ray bursts:

According to Jay Norris: Fluence of top 10% of bursts (highest fluence bursts) is 8 photons/(cm^2 s) between 50 and 300 keV

Of these, about 1/3 lie at energies above 200 keV, our worst-case scintillator threshold (Rate is upper limit as not all the energy goes into the Compton electron. Thus the effective threshold is higher on a steeply falling spectrum)

Any photon has about 10% chance of making a Compton electron in the 1cm thick plastic.
Rate of conversions from strong bursts:
< 0.3 photons/(cm^2 s) above 200 keV

What is the chance of having two tiles hit inside the resolving time interval?
2 * rate of hitting single tile * rate of hitting the remainder of the ACD * resolving time

2 x 0.3/(cm^2 s) x 1000 cm^2 x 0.3/(cm^2 s) x (160 cm x 160 cm [= max projected area of GLAST to point source]) x 10^-6 s = 4.6/s

Thus the fractional subset having a second photon convert in the ACD is 4.6/300 = 1.5%; this should be an acceptable loss.